LOUDNESS: CONTINUOUS SPECTRUM SOUND VERSUS HARMONIC SPECTRUM SOUND

R. ESPESSER, B. TESTON
Institut de Phonétique, CNRS LA 261, 13621 AIX EN PROVENCE(FRANCE)

Summary

An experiment is carried out to examine to what extent the loudness of voiced-unvoiced speech sounds is affected by the harmonic or continuous nature of their spectrum. Stimuli are synthesized by a 10 pole numeric filter simulating the transfer function of the vowel /ə/; this filter is excited either by white noise(lowpass filtered at 150 Hz, 6dB/oct) or by a square wave (F_o=150 Hz). The RMS energy and duration of the stimuli are alike. The subjects perform the loudness equalization task using the adjustment method.The effect prooved to be no significant; consequently no relation was found between the loudness and the specific nature of the spectrum.

Introduction

The loudness of a complex sound is related with its SPL,bandwidth, central frequency /1/ and the number of its spectral components/2/. In speech signals, the loudness of unvoiced segments is generally considered as lower than the loudness of their voiced counterparts. The question under examination can be stated as this: Is loudness of an acoustic segment related to the nature of its spectral structure?

1 Experimental procedure

1.1 Stimuli

They are synthesized by a SEMS T1600 computer with a 10 pole numeric filter(serial formant synthesizer /3,4/)simulating the transfer function of the neutral vowel/ə/ (fig.1). The vowel-like stimulus is produced by exciting this filter with a square

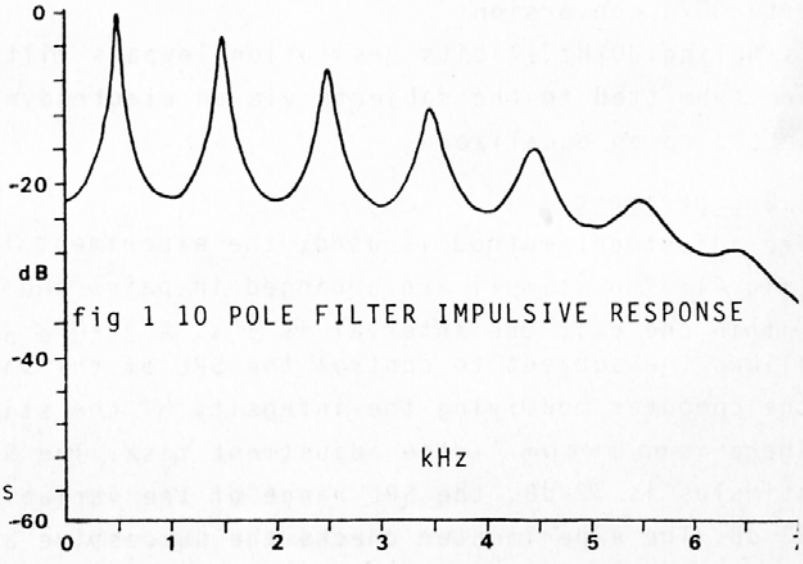

fig 1 10 POLE FILTER IMPULSIVE RESPONSE

wave(duty cycle:1/2 F_o:150 Hz);its spectrum is caracterized by odd harmonics with a 6 dB/oct.decay(fig 2). The noise-like stimulus is produced by exciting the filter with white noise,lowpass filtered at 150 Hz,6dB/oct. and highpass filtered at 150 Hz,60dB/oct.(fig 3). Thus the stimuli have the same spectral envelope.The duration of the stimuli is 200 ms with a raising slope of 25dB/40ms and a 20dB/5ms decay.The RMS energy(computed with a time constant of 70 ms)of the two competing stimuli is equalized within an 0.5dB interval.The stimuli, after D/A conversion (sampling:20kHz,12 bits resolution,lowpass filtering:6kHz,48dB/oct.) are submitted to the subjects via an electrodynamic loudspeaker connected to an equalizer.

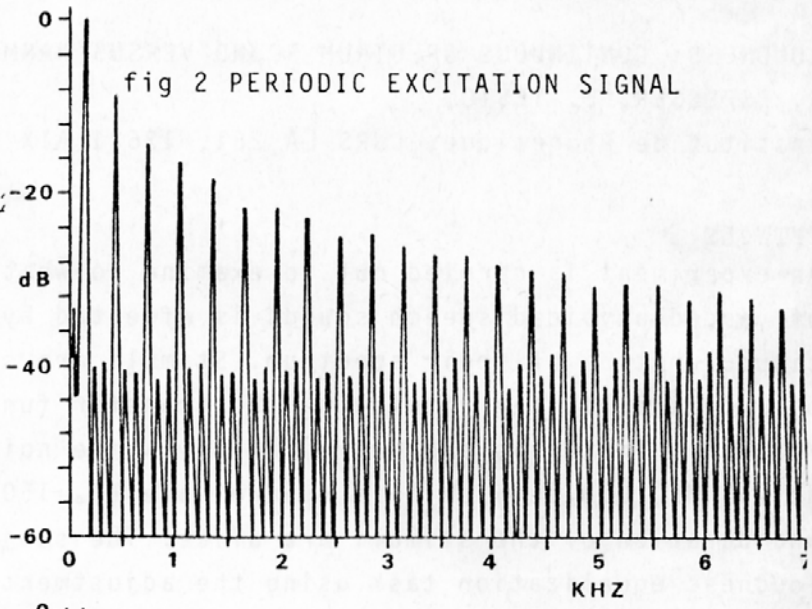

fig 2 PERIODIC EXCITATION SIGNAL

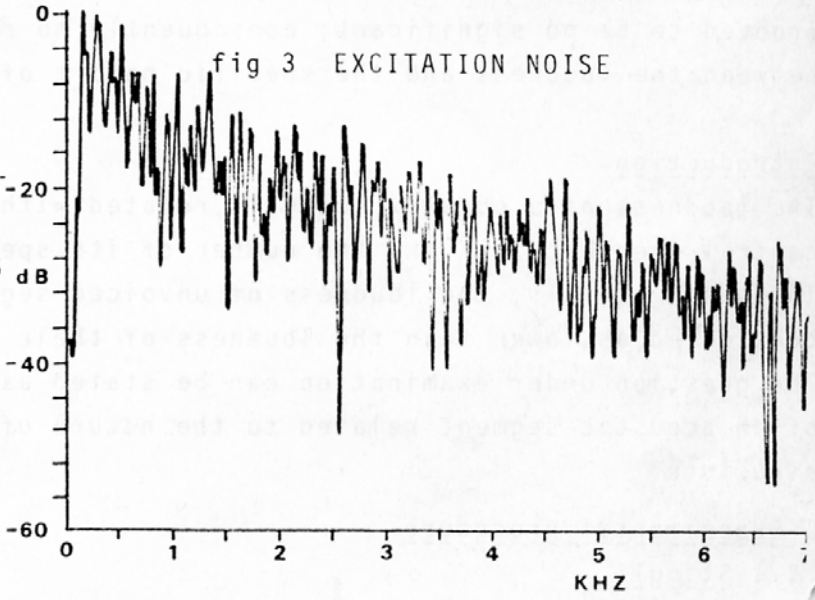

fig 3 EXCITATION NOISE

1.2 Experiment

The adjustment method is used; the experiment is computer controlled (fig 4). The stimuli are arranged in pairs and repeated every 3 s; within one pair the interval is 1 s. A 3-turn potentiometer allows the subject to control the SPL of the variable stimulus via the computer modifying the intensity of the stimulus in real time. There is no time limit in the adjustment task. The SPL of the reference stimulus is 72 dB, the SPL range of the variable stimulus is 62-82 dB. The experimenter checks the successive answers of the subject

on the graphic display.
20 subjects (students and members of the laboratory) take part in the experiment;there is a time interval of one week between the two listening sessions; each adjustment session is preceded by a short training phase in which the subject equalizes 2 identical stimuli("vowel/vowel" or "noise/noise").
The first session consists of 8 "vowel/noise" adjustments:4 adjustments with "vowel" as reference and 4 adjustments with "noise" as reference; the second session is identical to the first one in reverse order("noise/vowel").

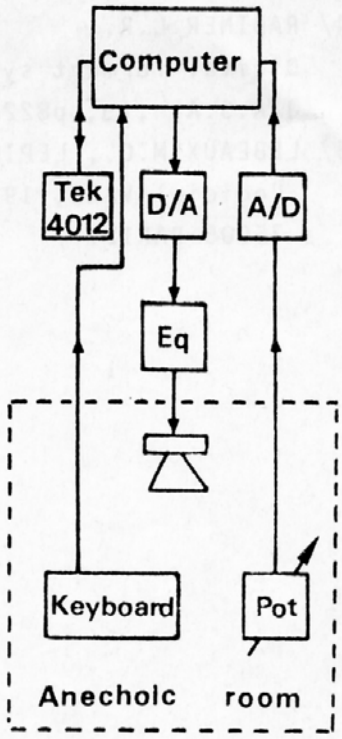

fig 4

2 Results and discussion

18 subjects have been retained. Analysis of variance(using the software VAR3 /5/) shows that results between vowel adjustment and noise adjustment are not significant ($F_{(1-17)}=2.03$). The well-known effects related to the order of presentation emerge. These effects are cancelled by the inversion of the presentation/variation order. As a conclusion, the loudness of speech-like sounds appears independent of the harmonic/continuous nature of its spectral structure.

References

/1/ ZWICKER E., FLOTTORP G., & STEVENS S.S.
Critical bandwidth in loudness summation, J.A.S.A. ,29,p548-557 1957

/2/ SCHARF B.
Loudness of complex sounds as a fuction of the number of components, J.A.S.A. ,31, p783-785, 1959

/3/ KLATT D.H.
Software for a cascade/parallel formant synthesizer J.A.S.A. ,68, p971-995, 1980

/4/ RABINER L.R.
Digital-formant synthesizer for speech-synthesis studies
J.A.S.A. ,43, p822-828, 1967
/5/ LEBEAUX M.O., LEPINE D. , ROUANET H.
Logiciel VAR3, 1976. SORBONNE, bureau 519,12 rue Cujas
75005 PARIS